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AUTONOMOUS INLAND SHIPPING: WILL THE BARGE OWNER BE STUCK 'BETWEEN THE DEVIL AND THE DEEP BLUE SEA'?

CAMILLA DOMENIGHINI*

ABSTRACT

Autonomous vessels for inland navigation may become a widespread reality soon. They will represent a disruption in the current business models, as much as in other transport sectors. Digital servitisation and concentration are the main trends. Current actors will change their roles, and others may disappear. Moreover, new actors, such as technology providers, are gaining importance. From a legal perspective, implementing autonomous barges requires not only a change in safety regulations but also a fair and balanced risk distribution among all the actors in the ecosystem. The analysis of liability and interest allocation in the contract chain shall not stop at traditional contracts and traditional actors. Looking at semi-autonomous navigation technology providers' terms and conditions will show how all the risks are passed to the shipowner/carrier, which on the other side, also bears mandatory liabilities. Such an arrangement disadvantages the introduction of autonomous vessels, discourages the stakeholders and worries the general public.

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Introduction

Autonomous technologies are developing fast also in slow transport, i.e. inland navigation. This paper will analyse the contractual issues arising from the introduction of autonomous barges. The text is divided into three parts. In the first part, inland shipping will be described as a sector with strengths and weaknesses that may gain in sustainability and reliability by introducing innovative technologies. Then, some definitions to distinguish concepts as "autonomous" and "automation" will be provided. The second part is composed of a literature review on the market disruption caused by the introduction of autonomous technologies in different transport sectors. From the results obtained, some possible directions are drafted for the future development of autonomous inland shipping. The third part focuses on contractual matters. A fair and balanced risk distribution may not only allow the introduction of autonomous barges but also act as a boost. For this reason, the allocation of liabilities and interests will be analysed starting from mandatory instruments such as the Budapest Convention on the Contract for the Carriage of Goods by Inland Waterway (CMNI) and moving to a voyage charterparty form for liquid bulk. These will be compared with the Terms and Conditions used by companies that already provide semi-autonomous navigation software on the market. Finally, it is argued that further research on the qualification of the technology providers is needed.

PART I AUTONOMOUS INLAND NAVIGATION

1. *Inland navigation, a (still) competitive mode over road transport?*

Navigation in European inland waterways is developed mainly in the ARA-Rhine region (Antwerp – Rotterdam – Amsterdam) and along the Danube area. Inland shipping is used to transport mainly dry bulk (iron ore, coal, sand and stones)[1], chemical and petroleum products[2]. Container transport in inland waterways amounted to 56.5 million tonnes and 6.8 million TEU in 2020, and it occurs only in the Rhine countries[3]. In Europe, among inland freight transport, inland navigation accounts for less than 10% of the modal split, while road haulage represents more than three-quarters of the total[4]. In the European Green Deal framework, the European

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[1] The registered European fleet counts more than 11.000 dry cargo vessels and less than 2.000 tankers. See Central Commission for the Navigation of the Rhine, *Annual Report 2021 Inland Navigation In Europe Market Observation*, 2021, p. 74.

[2] Central Commission for the Navigation of the Rhine, *Market Insight - Inland Navigation In Europe*, April 2022, p. 9.

[3] Central Commission for the Navigation of the Rhine, *Annual Report 2021 Inland Navigation In Europe Market Observation*, cit., p. 37. As an example, among the 56.5 million tonnes of the total EU container transport, 48,6 million tonnes passed through the Netherlands and 19.9 million tonnes through Belgium.

[4] European Commission. Statistical Office of the European Union, *Energy, transport and environment statistics: 2020 edition.*, Publications Office, LU 2020, p. 52.

Commission has set a priority goal for a modal shift from cargo carried by road to rail and inland waterways[5].

Inland shipping is recognised to have many advantages over road transport. In hyper-congested areas like port cities forwarding the cargo with barges instead of trucks can reduce the traffic. Even though in the last years, the market of new vessels has been orientated towards bigger ships[6], small barges (CEMT Class I or II, known as peniche, spits or kempenaar), which can navigate in smaller waterways and reach local industries, offer a solution to the last mile problem. Moreover, barges can potentially diminish the congestion in ports where they can be used as a mobile terminal in which ocean-going vessels unload their containers[7].

Inland shipping is considered one of the most sustainable modes of transport in terms of external costs, e.g. accidents, air pollution, climate, noise, and congestion[8]. However, this competitive advantage is slowly chipped away because inland vessels are generally old, with an average life of 60 years[9]. In this context, innovation fails to be implemented regularly[10]. This is true not only for technological innovation but also for business models. Inland navigation is a rather traditionalist sector where the main organisational model corresponds to a barge owner and its barge[11], which is also their house[12]. Such fragmentation in the supply is suboptimal for shippers who would rely on inland navigations to transport their cargo. Additionally, it strives hard competition between the carriers, contributing to very sharp margins when it comes to the shipowner's profit. Scholars[13] have proposed different solutions to this problem: shipowner companies may scale up with mergers and acquisitions, though

[5] EUROPEAN COMMISSION, *Communication From The Commission To The European Parliament, The European Council, The Council, The European Economic And Social Committee And The Committee Of The Regions - The European Green Deal*, 2019.

[6] Some of the causes lay in the difficulties in company succession, the technical issues of small vessels and the unfavourable financing conditions. Presentation by Dr. Norbert Kriegel at the Antwerpen Inland Navigation School 2022.

[7] See Novimove - Smart & sustainable waterways project.

[8] O. AL ENEZY - E. VAN HASSEL - C. SYS, T. VANELSLANDER, *Developing a cost calculation model for inland navigation*, in *Research in Transportation Business & Management*, 23, 2017, p. 65. See also F. HOFBAUER - L.M. PUTZ, *External Costs in Inland Waterway Transport: An Analysis of External Cost Categories and Calculation Methods*, in *Sustainability*, vol. 12, n. 14, 2020, p. 5874.

[9] C. SYS - E. VAN DE VOORDE - T. VANELSLANDER - E. VAN HASSEL, *De binnenvaart: traditionele modus, innovatieve toekomst?*, Research paper D/2017/1169/004, 2017, p. 14.

[10] *Ibid.*

[11] Cfr. E. VAN HASSEL, *Structuurverandering in het segment van de grote drogelading-binnenvaartschepen*, Working paper, 2013, at p. 8 it is indicated the number of inland shipping companies in Belgium and the Netherlands owning 1 or 2 ships (that means a ship and a push barge). The percentage is 98% for Belgium and 94% for the Netherlands. It should be noted that the data refer to 2008. At the contrary, in the Danube region, the share between vessel owners and barges is larger because the current companies derived from the privatization of public companies operating under the Soviet Union.

[12] This is especially true for the Rhine region, in this case it is worth noting that vessel owners develop a personal attachment to the barge, see E. VERBERGHT, *Innovation in inland navigation failure and success the European case*, 2020, p. 115.

[13] C. SYS - E. VAN DE VOORDE - T. VANELSLANDER - E. VAN HASSEL, *op. cit.*, p. 16.

this is rarely the case. Other different arrangements labelable as pooling management have been proposed[14].

1.2 *Automation in inland navigation*

In this landscape, technology is, however, advancing. Highly automated, unmanned and remote-controlled barges are already a reality, at least in Flanders (Belgium). In 2019, a decree of the Flemish government[15] on mobility policy, public works and transport set the standards for carrying out experiments about innovation in shipping.

Thanks to this decree, different companies have already started to test end exploit semi-autonomous navigation systems. For instance, Tresco has installed the Track Pilot on tens of barges; this software allows inland vessels to be automatically steered along a predetermined path. Seafar's technology is already used on a tanker, Gamma, and the estuary container ship Deseo. ArgoTrackPilot is an automatic track-keeping system for inland vessels along pre-defined guiding lines developed by Argonics GmbH. However, those automation systems and remote control shall not be confused with fully autonomous systems. The distinction is fundamental and radical, as it will be discussed further, and the presence and the role of humans are extremely relevant.

1.3 *Advantages of autonomous barges*

Autonomous inland navigation is understood to be greener, safer, cheaper (at least in the long term), faster, more flexible, and to increase the fleet capacity [16].

As newly built vessels, autonomous barges may integrate new generation engines that reduce emissions or even implement non-fossil fuel engines[17]. The AI controlling the barge will be able to plan in advance the voyage. Better planning will help reduce fuel consumption[18].

Autonomous inland vessels, as much as all the other transport vehicles, will be implemented when the technology will allow them to be "*as safe as manned shipping*"[19]. In transport, inland navigation is one of the most dangerous sectors

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[14] *Ibid.;* C. Sys - E. Van de Voorde - T. Vanelslander - E. van Hassel, *Pathways for a sustainable future inland water transport: A case study for the European inland navigation sector*, in *Case Studies on Transport Policy*, vol. 8, n. 3, 2020, p. 696.

[15] Vlaamse overheid [C – 2019/13067] 26 APRIL 2019. — Decreet houdende diverse bepalingen over het mobiliteitsbeleid, de openbare werken en het vervoer, het verkeersveiligheidsbeleid en VVM - De Lijn, in Belgisch staatsblad of 24 June 2019, p. 65071.

[16] E. Verberght, *Inn-in Innovative Inland Navigation*, 2019, p. 97.

[17] *Ibid.*, p. 145.

[18] E. Verberght - E. Van Hassel, *The automated and unmanned inland vessel*, in *J. Phys.: Conf. Ser.*, 2019, p. 1. Moreover, unmanned vessels will have no reason to rush to get first to locks, at a regular speed the fuel consumption is reduced.

[19] T. Porathe - Å. Hoem - Ø. Rødseth - K. Fjørtoft - S. O. Johnsen, *At least as safe as manned shipping? Autonomous shipping, safety and "human error,"* in *Safety and Reliability – Safe Societies in a Changing World*, CRC Press, 2018.

for its workforce[20] – in the Netherlands, for example, the risk of a fatal accident is almost six times higher than for truck drivers[21]. Unmanned barges will eliminate work accidents and fatalities for seafarers when they will represent the full fleet in the inland waterways[22]. Nevertheless, the presence of a human in the loop (i.e. in a remote control centre) will not eradicate human error in navigation. Those account for almost 80% of the accidents[23], even if the number is not acknowledged by all the scholars because databases are absent or jeopardised[24]. However, autonomous barges will naturally eliminate human errors leading to safer inland navigation.

Even though the initial investment would be more expensive than for a traditional barge[25], the autonomous barge will allow for cutting crew and accountability costs[26]. Moreover, the chartering and freight broker services will be increasingly digitalised, reducing the freight cost[27]. It is foreseen that – once proved the safety of the autonomous systems – eventually, the insurance cost will decrease[28], and it will sum up the economic advantages of autonomous barges.

Other predicted advantages concern the increased cargo capacity, assuming that the wheelhouse and living area[29] for the shipowner or the crew will be eliminated. Additionally, it has been calculated that an autonomous mooring system, an operation which is quite frequent in inland navigation, not only at berths to load and unload but also anytime passing a lock, will permit to save up to six days of navigation each year[30].

Moreover, the shortage of crew members and highly trained masters is a hassle for shipowners[31], and AI will represent a solution. Additionally, as said before,

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[20] NEA, *Final Report – Main Report, Medium – and Long-Term Perspectives of IWT in the European Union*, 2011, p. 198.

[21] *Ibid.*

[22] Incidents involving seafarers will remain a threat as far as non-autonomous barges will navigate in the waterways.

[23] K. Schreibers - R. Van der Weide - J. Rypkema - S. Van Es, *Human factors root causes of accidents in inland navigation: Organisational Aspects Phase 2b – Report*, 2021, p. 3.

[24] See I. Bačkalov - M. Vidić - S. Rudaković, *An analysis of accidents in inland navigation in context of autonomous shipping*, in *Proceedings of the 1st International Conference on the Stability and Safety of Ships and Ocean Vehicles*, Conference paper 2021. The authors, who considered the Austrian and Serbian parts of the Danube, state "*the analysis presented in this paper did not confirm that the human failures could be responsible for as much as e.g. 80% of accidents. Considering that human failures caused less than 60% of accidents in Austria, and less than 20% of accidents in Serbia, it seems that the influence of human failures may be exaggerated, at least in case of inland navigation on the Danube and the Sava, and that it could well depend on the navigational conditions on a specific waterway and the level of safety attained by the design and maintenance of ships in a specific fleet.*"

[25] E. Verberght - E. Van Hassel, *op. cit.*, p. 3.

[26] *Ibid.*

[27] *Ibid.,* p. 4.

[28] *Ibid.*

[29] Barges which belong to family businesses are generally equipped with barge-owner apartments, which are in fact their home.

[30] *Ibid.,* p. 131.

[31] X. Zhang - Q. Zhang - J. Yang - Z. Cong - J. Luo - H. Chen, *Safety Risk Analysis of Unmanned Ships in Inland Rivers Based on a Fuzzy Bayesian Network*, in *Journal of Advanced Transportation*, 2019, p. 1.

inland navigation still enjoys a competitive advantage over road transport, and it is still considered more sustainable than the latter; this, however, is deemed to change soon, as other transport sectors adapt to technology faster – the lifespan of trucks, for example, is of few years before being sold off outside Europe to developing countries, and this fosters the adoption of greener and innovative technologies in the newly built vehicles. Automation technologies and eventually autonomous systems are a change that inland navigation cannot miss to remain competitive[32].

1.4 *Research projects on inland navigation*

Autonomous navigation in inland waterways has also caught the European Commission's interest. The implementation of autonomous barges for smart inland shipping is one of the goals presented in the Naiades III 2021-2027 action plan[33]. Moreover, different projects have been financed to research the sector and, more specifically, the opportunity for automatisation.

Some of those projects focus on the design of innovative barges for small waterways and low waters, able to adapt to cargo needs ensuring flexible transportation thanks to coupling and decoupling systems and platooning (i.e. Novimar and Watertrucks+); others tackle inland navigation from a broader perspective working on improving the whole environment, such as Novimove. Finally, two projects, i.e. Autoship and Autobarge (of which this research is part), target autonomous navigation in inland waterways with an interdisciplinary approach where the engineering research is paired with the study of socio-technical, economic, logistic and legal aspects.

1.5 *Autonomous vs automation*

As noted above, it is vital to distinguish between remotely operated vessels and fully autonomous vessels. In many cases, the difference between manned and unmanned ships may be misleading. Both an autonomous and a remotely operated vessel may be unmanned or manned (e.g. personnel onboard may be employed without navigation roles for tasks such as passengers supervision and daily maintenance).

The real difference lies in who or what has control of the vessel. In the case of remote control and operation, the master (ideally ashore but anyway relocated to an off-board wheelhouse) with the support of cameras, sensors, radar, RIS, and other technologies, steers the barge, moors, contacts lock and bridge's operators, queues the barge at terminals, and acts almost entirely as a master onboard. Remote-controlled barges will implement digital and automatic technologies, and the operator may even get assisted by artificial intelligence tools, as is already the case with the crew and master on the vessel (for example, the autopilot). Still, humans will always stay in the loop.

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[32] E. Verberght - E. Van Hassel, *op. cit.*, p. 1.

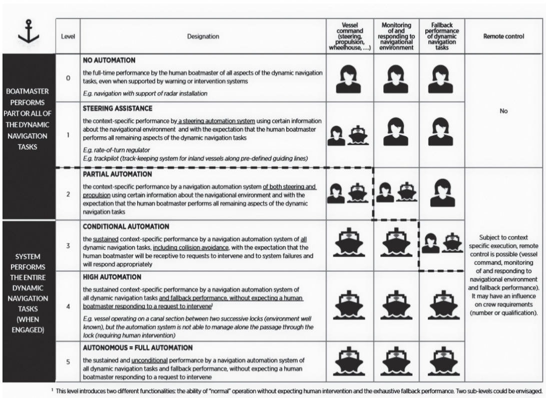
[33] European Commission Com(2021) 324 final Communication From The Commission To The European Parliament, The Council, The European Economic And Social Committee And The Committee Of The Regions: Naiades III: Boosting future-proof European inland waterway transport.

In the case of fully autonomous vessels, an autonomous navigation system equipped with artificial intelligence algorithms will perform all those tasks. The ship will gather data from different sources (cameras, radar, LIDAR, sensors, GPS, RIS, weather forecasting, etc.) to sense the context on board and in the environment, and she will be able to communicate and receive information from other ships, locks and bridges' operators (either manned or autonomous). Also, she will plan the voyage in advance and adapt the trajectory and the speed to avoid obstacles (both fixed and mobile) and prevent collision and allision. The algorithm will predict the behaviour of other waterways' users, issue digital documents and more.

Different stages need to be reached in the path toward fully autonomous navigation, and different levels of automatisation are possible.

For the maritime sector, different classifications have been proposed by many organisations. The "MASS Industry Conduct Principles & Code of Practice version 4" by Maritime UK provides seven levels of control[34]. As many as the Lloyd's Register classification[35]. IMO's levels of autonomy are, instead, only four[36]. DNV identified five levels[37], while Bureau Veritas distinguishes five degrees of automation and eight of control (divided into direct control and remote control)[38].

For inland navigation, the Central Commission for the Navigation on the Rhine (CCNR) has developed a matrix with five levels[39].



	Level	Designation	Vessel command (steering, propulsion, wheelhouse, …)	Monitoring of and responding to navigational environment	Fallback performance of dynamic navigation tasks	Remote control
BOATMASTER PERFORMS PART OR ALL OF THE DYNAMIC NAVIGATION TASKS	0	**NO AUTOMATION** the full-time performance by the human boatmaster of all aspects of the dynamic navigation tasks, even when supported by warning or intervention systems *E.g. navigation with support of radar installation*				No
	1	**STEERING ASSISTANCE** the context-specific performance by a steering automation system using certain information about the navigational environment and with the expectation that the human boatmaster performs all remaining aspects of the dynamic navigation tasks *E.g. rate-of-turn regulator* *E.g. trackpilot (track-keeping system for inland vessels along pre-defined guiding lines)*				
	2	**PARTIAL AUTOMATION** the context-specific performance by a navigation automation system of both steering and propulsion using certain information about the navigational environment and with the expectation that the human boatmaster performs all remaining aspects of the dynamic navigation tasks				Subject to context specific execution, remote control is possible (vessel command, monitoring of and responding to navigational environment and fallback performance). It may have an influence on crew requirements (number or qualification).
SYSTEM PERFORMS THE ENTIRE DYNAMIC NAVIGATION TASKS (WHEN ENGAGED)	3	**CONDITIONAL AUTOMATION** the sustained context-specific performance by a navigation automation system of all dynamic navigation tasks, including collision avoidance, with the expectation that the human boatmaster will be receptive to requests to intervene and to system failures and will respond appropriately				
	4	**HIGH AUTOMATION** the sustained context-specific performance by a navigation automation system of all dynamic navigation tasks and fallback performance, without expecting a human boatmaster responding to a request to intervene[1] *E.g. vessel operating on a canal section between two successive locks (environment well known), but the automation system is not able to manage alone the passage through the lock (requiring human intervention)*				
	5	**AUTONOMOUS = FULL AUTOMATION** the sustained and unconditional performance by a navigation automation system of all dynamic navigation tasks and fallback performance, without expecting a human boatmaster responding to a request to intervene				

[1] This level introduces two different functionalities: the ability of "normal" operation without expecting human intervention and the exhaustive fallback performance. Two sub-levels could be envisaged.

Figure 1 *Automation levels in inland navigation. CCNR 2018*

[34] MARITIME UK, *Maritime Autonomous Surface Ships Industry Conduct Principles & Code of Practice version 4*, 2020, p. 20.

[35] LLOYD'S REGISTER, *Design Code for Unmanned Marine Systems, February 2017*, 2017.

[36] INTERNATIONAL MARITIME ORGANIZATION, *MSC.1-Circ.1638 - Outcome Of The Regulatory Scoping Exercise For The Use Of Maritime Autonomous Surface Ships (MASS)*, 2021, pp. 3-4.

[37] DNV, *Class Guideline - Autonomous and remotely operated ships - dnvgl-cg-0264*, 2018, p. 51.

[38] BUREAU VERITAS, *Guidelines for autonomous shipping NI 641 DT R01 E*, 2019, pp. 10-11.

[39] CENTRAL COMMISSION FOR THE NAVIGATION OF THE RHINE, *First International Definition Of Levels Of Automation In Inland Navigation Ref : CC/CP (18)20*, 2018.

Those levels may coexist even in the same voyage: for example, the remote-controlled barge, in case of trouble, is supposed to be able to harbour autonomously until the connection with the remote control centre is re-established[40].

The autonomous barge corresponds to levels 4 and 5 of the CCNR classification, where the barge can perform all the tasks either in a limited area or unconditionally. Anyhow, the barge will not rely on the master or operator, removing the human in the loop.

Scholars stated that, differently from the car industry, the maritime industry prefers to keep the human in the loop, to react if necessary. As ships are more capital-intensive than cars and potential damage is very high, it is "*more cost-effective to invest in remote control centres with personnel that can supervise autonomous ship operations and also intervene in complex and potentially dangerous situations*"[41].

1.6 *Autonomous inland navigation risks*

As stated before, implementing an autonomous navigation system will eliminate human error but will not eradicate all the risks. Some authors[42] have tried to describe those risks for sea-going vessels and inland navigation.

Among the traditional vessel factors of risk, ship-related and environment-related risks will persist. A not exhaustive list could mention unseaworthiness, failure of the ship equipment, lack of maintenance, structural strength, nature of the cargo, visibility, speed, weather, and traffic conditions. Moreover, failure of the software, the hardware and fail-safe mechanisms, violation of the operational design domain, loss of connection, data quality, computational complexity, lack of updates, and cyber-attack will be added risks with the increased implementation of autonomous technology.

While both the transport modes share some common risks, it is necessary to consider the inland navigation case alone, as it presents different risk factors. The waterways can be very narrow and densely navigated, not only by commercial vessels but also by sport and touristic boats. Tidal rivers are risky, especially when debris are on the riverbed. The navigation is often interrupted at bridges, locks and quays. Moreover, technologies implemented in the maritime sector may not be

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40 For example, unmanned remote-controlled barges by Seafar apply a preventive approach. Equipped with multiple connections, the barge freezes in case some of them are lost, and it does not operate with only one connection. It will be duty of standardizing bodies, such as CESNI for inland navigation, to set rules for the equipment and the procedure to follow.

41 Ø. J. Rødseth - L. A. Lien Wennersberg - H. Nordahl, *Towards approval of autonomous ship systems by their operational envelope*, in *Journal of Marine Science and Technology*, vol. 27, 2022, p. 71.

42 X. Zhang - Q. Zhang - J. Yang - Z. Cong - J. Luo - H. Chen, *op. cit.*, 2019, p. 6; C. Fan - K. Wróbel - J. Montewka - M. Gil - C. Wan - D. Zhang, *A framework to identify factors influencing navigational risk for Maritime Autonomous Surface Ships*, in *Ocean Engineering*, 2020, pp. 9-10.

easily duplicated on inland navigation because of the too high cost[43] or the lack of position accuracy in restricted areas (i.e. GNSS)[44].

PART II MARKET DISRUPTION

2.1 *Business model disruption in road and sea transport sectors*

Transport and management literature seems to agree that autonomous systems applied to transportation will determine a disruption of the current business models, a change in traditional actors' positioning and the entry into the market of new protagonists[45].

An analysis of the possible disruption is completely lacking in the inland navigation sector; for this reason, research on the implementation of autonomous systems in short sea shipping, road transport and ocean shipping has been considered[46].

The scholars agree that there will be a shift in the understanding of the property of the ship and trucks. Autonomous ships permit a variety of commercial configurations with different models of ownership and revenue[47]. Understanding

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[43] Q. Ai, X. Qiao, Y. Liao, Q. Yu, *Joint Optimization of USVs Communication and Computation Resource in IRS-aided Wireless Inland Ship MEC Networks*, in *IEEE Transactions on Green Communications and Networking*, 2021, p. 1.

[44] S. Alissa, M. Håkansson, P. Henkel, U. Mittmann, J. Hüffmeier, R. Rylander, *Low bandwidth network-rtk correction dissemination for high accuracy maritime navigation*, in *TransNav*, vol.15, n.1, 2021, p. 172.

[45] H. R. Askari - M. N. Hossain, *Towards utilizing autonomous ships: A viable advance in industry 4.0*, in *Journal of International Maritime Safety, Environmental Affairs, and Shipping*, vol. 6, n. 1, 2022, pp. 39-49; M. Kim - T.H. Joung - B. Jeong - H.S. Park, *Autonomous shipping and its impact on regulations, technologies, and industries*, in *Journal of International Maritime Safety, Environmental Affairs, and Shipping*, vol. 4, n. 2, 2020, pp. 17-25; H. Ghaderi, *Wider implications of autonomous vessels for the maritime industry: Mapping the unprecedented challenges*, in D. Milakis - N. Thomopoulos - B. van Wee (edited by), *Advances in Transport Policy and Planning* (*Policy Implications of Autonomous Vehicles*), vol. 5, Academic Press, 2020, pp. 263-289; B. Wiśnicki - N. Wagner - P. Wołejsza, *Critical areas for successful adoption of technological innovations in sea shipping – the autonomous ship case study*, in *Innovation: The European Journal of Social Science Research*, 2021, pp. 1-27; H. O. Sandvik - D. Sjödin - T. Brekke - V. Parida, *Inherent paradoxes in the shift to autonomous solutions provision: a multilevel investigation of the shipping industry*, in *Service Business,* 2021; A. Tsvetkova - M. Hellström, *Creating value through autonomous shipping: an ecosystem perspective*, in *Maritime Economics & Logistics*, 2022; A. Tsvetkova - M. Hellström - H. Ringbom, *Creating value through product-service-software systems in institutionalized ecosystems – The case of autonomous ships*, in *Industrial Marketing Management*, vol. 99, 2021, pp. 16-27; C. Fritschy - S. Spinler, *The impact of autonomous trucks on business models in the automotive and logistics industry – a Delphi-based scenario study*, in *Technological Forecasting and Social Change*, vol. 148, 2019, pp. 119736; J. Monios, R. Bergqvist, *Logistics and the networked society: A conceptual framework for smart network business models using electric autonomous vehicles (EAVs)*, in *Technological Forecasting and Social Change*, vol. 151, 2020, p. 119824.

[46] Data have been gathered with a literature review conducted with Google Scholar using the following keywords "*autonomous truck business model*" and "*autonomous ship business model*".

[47] H. O. Sandvik - D. Sjödin - T. Brekke - V. Parida, *op. cit.*, p. 15.

autonomous vessels as a service is the key element of this change[48].

In general, the trend foreseen is deepening in the servitisation[49] of the manufacturing and operations, and a process towards digital servitisation[50].

The trend seems to indicate a path towards a network-based business where interactions and stable links among all the actors in the ecosystem apply, both in the manufacturing phase and the operational one, not only for the recurrent maintenance and upgrading. In a network-based business model, a single firm alone does not suffice to provide the product or the service and needs to rely on others[51]. Management scholars have stated that this will bring a huge change in the business model and will be best governed by outcome-based contracts[52].

Network alliances and agreements may also come from the possibility – enhanced with autonomous systems – of platooning[53].

2.2 *The manufacturer*

Munim[54] looks especially at the role of the autonomous ship manufacturer. With autonomous vessels, shipyards have the possibility to offer both ownership and vessel-sharing services to their clients. The sale of the ship will go together with after-sale service, which can be offered with "service packages", including maintenance and periodic updates of both hardware and software[55]. It is worth noting from now, but it will be discussed below, that – according to some authors[56] –

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[48] Z.H. Munim, *Autonomous ships: a review, innovative applications and future maritime business models*, in *Supply Chain Forum: An International Journal*, vol. 20, n. 4, 2019, *passim*.

[49] *Ibid.*; J. O. Strandhagen - L. R. Vallandingham - G. Fragapane - J.W. Strandhagen - A. B. H. Stangeland - N. Sharma, *Logistics 4.0 and emerging sustainable business models*, in *Advances in Manufacturing*, vol. 5, n. 4, 2017, pp. 359-369.

[50] *Ibid.* and also in A. Tsvetkova - M. Hellström - H. Ringbom, *op. cit.*, Digital servitization is described by H. Gebauer - M. Paiola - N. Saccani - M. Rapaccini, *Digital servitization: Crossing the perspectives of digitization and servitization*, in *Industrial Marketing Management*, vol. 93, 2021, pp. 382-388, as the convergence of digitalization and servitization. The latter concept stands for a shift in the value from the property of the product to the service it can be used for, this is enhanced with the integration of digital technologies. In M. Kohtamäki - V. Parida - P. Oghazi - H. Gebauer - T. Baines, *Digital servitization business models in ecosystems: A theory of the firm*, in *Journal of Business Research*, n. 104, 2019, pp. 380-392, digital servitisation is described as "*the transition toward smart product-service-software systems that enables value creatin and capture through monitoring, control, optimization, and autonomous function*."

[51] F. Lind - L. Melander, *Networked business models for current and future road freight transport: taking a truck manufacturer's perspective*, in *Technology Analysis & Strategic Management*, 2021, p. 4.

[52] H.O. Sandvik - D. Sjödin - T. Brekke - V. Parida, *op. cit.* p. 2.

[53] Z.H. Munim, *op. cit.* p. 9; W. Verheyen, *Toward a model for sustainable platooning cooperation in road transport*, in E. Eftestøl-Wilhelmsson, S. Sankari, A. Bask (edited by), *Sustainable and efficient transport*, Edward Elgar Publishing, 2018; J. Monios, R. Bergqvist, *op. cit.*, p. 8.

[54] Z.H. Munim, *op. cit.*

[55] *Ibid.*, p. 8; cfr. note 61.

[56] H. Ghaderi, *Wider implications of autonomous vessels for the maritime industry*, *cit.*, p. 276; H. O. Sandvik - D. Sjödin - T. Brekke - V. Parida, *op. cit.* p. 24.

given the complexity of the technology also for the maintenance, the manufacturers will need to contract a partnership with the technology provider. On autonomous vehicles, ships or trucks, maintenance has a lot to do also with collecting data, both historical and in real-time. These data are relevant both for insurance purposes[57] and for improving the service offered by the manufacturer. On the other hand, ownership models of autonomous vehicles may present fewer incentives because of the high cost and the obsolesce[58]. Though, the shipyards may rent the autonomous vessel on a pay-per-use basis, acting as a shipowner time or voyage chartering the ship[59].

In the road transport sector, truck manufacturers already sell or lease the vehicles and offer maintenance and aftersales services packages[60]. However, it is foreseen that truck manufacturers may decide to retain the vehicle's property and offer on the market "capacity as a service"[61] and charge per km or tkm[62]. The decision of the manufacturer to become transport providers may create tension with their current customers, but it has been considered "necessary for long-term survival"[63]. Monios and Bergavist[64] present the case of a Norwegian mine company which does not buy the autonomous trucks produced by Volvo to use on their private property but purchases the transport service provided by the manufacturer. As it will be shown below, the tendency is to bypass the traditional transport provider and operator.

Depending on the skills owned, the shipyard may decide to develop and produce the autonomous vessel in-house[65]. Those skills may also be built-in inside the industry, but this may involve a change in the role of the manufacturer within the ecosystem[66]. Nevertheless, the shipyard may decide to outsource part of the production phases. This option may be the most realistic one for most shipbuilders, given the high degree of complexity that autonomous systems involve[67]. The most obvious partnership for the manufacturer is the one with the software provider[68]. In this way, the manufacturer will become a "system integrator"[69].

However, the preeminent role of the manufacturer itself in the traditional chain is challenged with autonomous ships: Sandvik et al. note that, while traditionally,

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57 A. Tsvetkova - M. Hellström, *op. cit.* p. 11.
58 J. Monios - R. Bergqvist, *op. cit.* p. 1.
59 Z.H. Munim, *op. cit.* p. 7.
60 F. Lind - L. Melander, *op. cit.* p. 6; J. Monios - R. Bergqvist, *op. cit.* p. 1.
61 C. Fritschy, S. Spinler, *op. cit.* p. 7.
62 J. Monios, R. Bergqvist, *op. cit.* p. 3.
63 *Ibid.* p. 4.
64 *Ibid.* p. 3.
65 Z. H. Munim, *op. cit.* p. 8.
66 H.O. Sandvik - D. Sjödin - T. Brekke - V. Parida, *op. cit.* p. 16.
67 H. Ghaderi, *Wider implications of autonomous vessels for the maritime industry*, *cit.* p. 275.
68 C. Fritschy - S. Spinler, *op. cit.* p. 1.
69 H. Ghaderi, *Wider implications of autonomous vessels for the maritime industry*, *cit.*, p. 275.

the vessels are commissioned to the shipyard, the tendency is now to order them from the technology provider, which then gathers tenders from shipyards[70].

2.3 *The suppliers and the tech provider*

In this context, new actors will enter the scene. The suppliers of the shipbuilder will represent a complex network providing services and products, possibly responsible for the development of the software and the most technologically advanced parts[71].

Tech providers may license their solutions to third parties, as much as manufacturers can do if they develop the technology in-house[72]. Instead of licensing the software, the company may offer the software as a service (SaaS), deliver the infrastructure – the hardware – and continuous maintenance service. Authors have pointed out how the position of the technology providers will need to deal with the paradox in which they collaborate closely with the ecosystem partners, but at the same time, their goal is to become leading parts of the same ecosystem[73].

The tech supplier relationships, however, do not stop at the shipyard or are limited to the truck manufacturer. Partnerships between the ICT developers and ship management companies will supply autonomous navigation services. Moreover, they may also assume a more central role in operating their own software on ships and trucks, providing a transport service.

2.4 *Shipping management toward network operator?*

In the analysis of the trend of autonomous ship use in short sea shipping, Ghaderi foresees the creation of new ship management companies, which are "*independent organisations [that] provide autonomous ship management service on a subscription model basis*"[74]. Operating multiple vessels at the same time can, in fact, reduce the operational (OPEX) and capital (CAPEX) costs[75], and this is not possible if the shipowner's fleet is composed only of few ships, and, as said above, this is especially the case in inland shipping. Other authors have identified a new kind of business model, particularly in semi-autonomous navigation or whenever humans must be in control of the ship through a Shore Control Centre (SCC). As just noted, shipowners may not be interested in setting up an SCC, it may be too expensive, or they may lack the right expertise. For this role, both the

[70] H O. Sandvik - D. Sjödin - T. Brekke - V. Parida, *op. cit.* p. 17.

[71] H. Ghaderi, *Wider implications of autonomous vessels for the maritime industry*, *cit.* p. 275.

[72] Z.H. Munim, *op. cit.* p. 8.

[73] H.O. Sandvik - D. Sjödin - T. Brekke - V. Parida, *op. cit.* p. 17.

[74] H. Ghaderi, *Wider implications of autonomous vessels for the maritime industry*, *cit.* p. 270.

[75] *Ibid.*

ship manufacturer[76] and the technology provider[77] have been proposed by the literature. In the road transport management research[78], a new figure is foreseen: the network operator, which will be the entity providing the transport service managing a large number of autonomous trucks; it will substitute the traditional operators and may choose the best solution for the asset management[79]. The identity of the network operator is open: it may be the manufacturer, the ICT provider, a large shipper, etc.[80].

2.5 *The role of the ship and truck owner*

The most acknowledged knockback of autonomous shipping, as soon as regulations will allow it, is the obsolescence of crew and master. Nevertheless, many other traditional actors may be affected by the introduction of this technology. It has been forecasted that the capital cost of an autonomous vessel may be so high to hamper this investment to small and medium-size operator companies[81]. Moreover, small owner-operators may be outed from the market by the monopolistic behaviour of large (shipping) companies that may take advantage of the high cost of the technology to compete aggressively against smaller competitors[82]. Monios and Bergqvist[83] note that as owner-operator are useless when trucks are driverless, small owners will disappear first in long hauling routes and, with the development and spread of the technology, they will also disappear from the short hauling market. Additionally, some authors[84] warned that such a complex ecosystem might lead to role exploitation and marginalisation of some traditional actors.

Scholars have pointed out that at this stage, it is not clear yet which actor will actually benefit from the implementation of autonomous vessels[85]. Whether it will be the suppliers, the shipyards, the owner or the operators will also depend on contracts. For example, it has been stated that one of the main gains from the introduction of autonomous navigation will derive from reduced fuel consumption. Depending on charter contracts, bunkering is at the expense of the owner or of the charterer (respectively in the case of voyage chartering and time chartering);

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76 Z. H. Munim, *op. cit.* p. 7.

77 A. Tsvetkova - M. Hellström - H. Ringbom, *op. cit.* p. 22.

78 J. Monios - R. Bergqvist, *op. cit.* pp. 7 and ff.

79 It is worth noting that in *Ibid.* the authors describe different business models. In one of the proposed model the ownership (after small owner operators have been out-marketed) is still consolidated in one entity, in the following model, ownership is not important and the network operator will order the needed trucks from a pool of providers.

80 *Ibid.*

81 H. Ghaderi, *Wider implications of autonomous vessels for the maritime industry*, *cit.*, p. 283.

82 H. Ghaderi, *Autonomous technologies in short sea shipping: trends, feasibility and implications*, in *Transport Reviews*, vol. 39, n. 1, 2019, p. 169; J. Monios - R. Bergqvist, *op. cit.* p. 7.

83 J. Monios - R. Bergqvist, *op. cit.* p. 8.

84 H.O. Sandvik - D. Sjödin - T. Brekke - V. Parida, *op. cit.* p. 18.

85 A. Tsvetkova - M. Hellström - H. Ringbom, *op. cit.* p. 14.

while it is still possible that this saving could be reflected on the freight, authors argue that whether operators do not have a direct gain will have little incentives on choosing an autonomous ship[86].

The cost of the technology and the operations may change the transport chain; in this disruption, shipowners may become outmoded. Many authors agree that shippers may bypass shipowners or transport providers[87]. Ghaderi[88] notes how the cargo owners may face exponential savings if they own and operate the autonomous vessel. This is confirmed by the demand trend for unmanned ships from good owners rather than from shipowners[89]. While traditional actors are more risk-averse, non-maritime agents are looking for business opportunities brought by autonomous systems, and those innovative solutions may push out boundaries to enter the shipping sector[90].

Autonomous shipping can be the point of no return for supply businesses to vertically integrate the whole logistic chain bypassing shipowners and co-developing with tech providers tailor-made solutions, eventually controlling the supply chain end to end[91].

2.6 *Logistic disruption*

Moreover, alongside artificial intelligence to navigate autonomous ships and drive autonomous trucks, the development of other technologies such as the Internet of Things and cloud computing will permit connected freight and modular ships and the development of new concepts such as Shipping as a Service[92]. Autonomous ships can become "floating stock", enhancing the tradable nature of the cargo and being flexible enough to redirect to any port[93]. This context will allow fourth-part-logistic (4PL) to grow by employing ICT service providers[94].

2.7 *The inland navigation market*

As seen above, the inland shipping market in the Rhine region is characterised by a fragmented supply, among which owner-operators represent an important

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[86] *Ibid.*; A. Tsvetkova - M. Hellström, *op. cit.* p. 17.

[87] H. Ghaderi, *Autonomous technologies in short sea shipping*, *cit.*; H.O. Sandvik - D. Sjödin - T. Brekke - V. Parida, *op. cit.* p. 21; A. Tsvetkova - M. Hellström, *op. cit.* pp. 19 ff.

[88] H. Ghaderi, *Autonomous technologies in short sea shipping*, *cit.,* p. 169.

[89] H.O. Sandvik - D. Sjödin - T. Brekke - V. Parida, *op. cit.* p. 17.

[90] *Ibid.*

[91] A. Tsvetkova - M. Hellström, *op. cit.*; pp. 2, 19. H.O. Sandvik - D. Sjödin - T. Brekke - V. Parida, *op. cit.* p. 21.

[92] H. Ghaderi, *Wider implications of autonomous vessels for the maritime industry*, *cit.*

[93] A. Tsvetkova, M. Hellström, *op. cit.* p. 13.

[94] K.A. Hribernik - K. D. Thoben - O. Herzog - A. Schuldt - J.D. Gehrke, *Towards Fourth-Party Logistics Providers – A Business Model for Cloud-Based Autonomous Logistics*, in *Proceedings of the first International Conference on Cloud Computing and Services Science*, 2011.

share[95]. This business model reduces the bargaining power of the vessel owners, it makes them vulnerable to market volatility and does not allow them to invest in innovation[96]. Depending on freight rates and willingness to be independent, shipowners may work on liner services, tramp shipping (spot market), or time charting their barge to a *bevrachter* (charterer)[97].

In the case of tramp shipping, the barge operators receive offers to transport cargo directly from shippers or – more commonly – through cargo brokers or intermediaries, in Dutch *bevrachtermakelaar*[98]. However, the same companies that work as brokers generally act as charterers for shipowners who accept yearly or longer contracts of time chartering[99]. In this case, they are the contractual carrier with the shippers or *vervoerscommissionnair*[100]. Although the two figures are contractually very different, they are both known as *bevrachter.* This structure creates two separate markets, one between the shipper and the broker and a second one between the latter and the barge owner[101], where the skipper is not really aware of the freight offered by the shippers and consequently of the broker's provisions[102]. However, scholars have noted that the role of brokers may be less necessary in the inland navigation world, and they are getting more and more absorbed into big firms or replaced by online platforms[103]. The market changes in the case of container transport because it is almost entirely dependent on high sea shipping and ocean carriers organise it[104]; this also explains why this sector is developed only in the Rhine region where the most important ports are located (Antwerp – Rotterdam – Amsterdam). The inland container transport is provided by barge-container-operator with their owned barges or hired barges in case of high demand[105]. Finally, the market for tankers differs ulteriorly because of the European Barge Inspection Scheme, which strictly links the freight broker and the skippers and helps the first to become bigger firms and consolidate their market position[106].

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95 E. VERBERGHT, *Innovation in inland navigation failure and success the European case*, *cit.*, p. 7.

96 *Ibid.*, Moreover, if the barge owner owns only one barge, in case of accidents or whenever the vessel has to dry dock the income is inevitably stopped.

97 C. SYS - F. HELLEBOSCH, *Binnenvaart theorie en praktijk*, Academia Press, Gent, 2021, p. 419.

98 *Ibid.*, p. 421.

99 *Ibid.*, p. 426.

100 *Ibid.*

101 E. VAN HASSEL, *op. cit.*; C. SYS, E. VAN DE VOORDE - T. VANELSLANDER - E. VAN HASSEL, *Pathways for a sustainable future inland water transport*, *cit.*, p. 692.

102 C. SYS - F. HELLEBOSCH, *op. cit.,* p. 30.

103 *Ibid.*, p. 428.

104 *Ibid.*, p. 430.

105 *Ibid.*, p. 432.

106 E. VERBERGHT, *Innovation in inland navigation failure and success the European case*, *cit.*, p. 10.

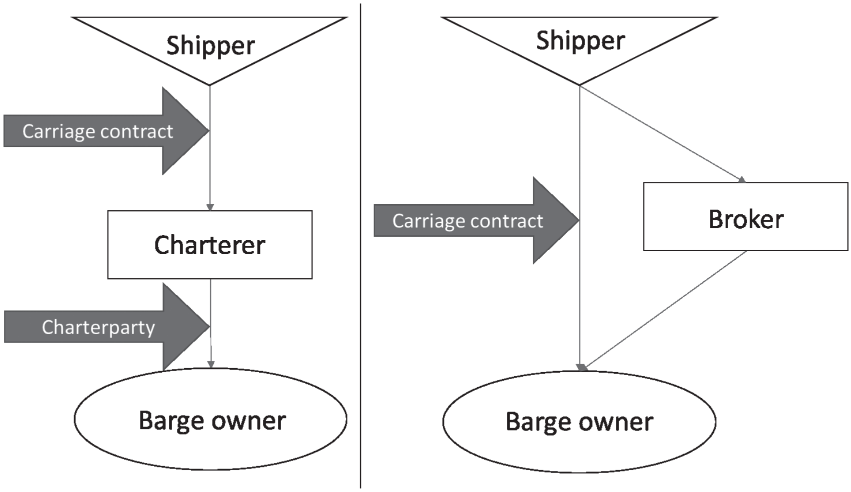

Figure 2 *Schemes of carriage contract chain with and without a charterer. Author's own composition*

2.8 *Disruption in the inland navigation market*

Even though there is no research on the possible disruption in the inland shipping market, some trends can be delineated by looking at the proximal transport sectors.

In a market composed for the majority of skipper-owners, the investment required to buy an autonomous barge will evidently be complicated and require the trust of financing institutions. However, given the strict bond between shipowner and broker/charterer, a partnership between the two may be envisaged to co-invest in an autonomous vessel[107]. Another option is, of course, retrofitting, implementing automated solutions on existing barges. The implementation of autonomous barges – which are very expensive and grant a benefit only if managed in multiple numbers simultaneously – may convince skippers who are traditionally unwilling to cooperate to join forces and create pools and cooperatives that may change the market.

However, confirming the tendency for bigger players to compete in the new market is the order placed by Naval Inland Navigation for ten semi-autonomous vessels for container and dry cargo that will be remotely controlled. Notably, the project, that will implement the technology from Seafar, has been coordinated with the tech provider as proof of a new central role for these actors. Moreover, this implies a strict collaboration between the manufacturer and the technology provider.

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[107] *Ibid.*, p. 9.

Moving from the shipbuilding and the ownership, questions also arise on how those autonomous barges will be operated. As the cost of setting up a Shore Control Centre is very high and it is economically feasible only when multiple barges are controlled simultaneously, this service may be provided by independent ship managers. It is indeed the case of Seafar, which on its website describes itself as "*an independent ship management company, offering services to operate unmanned and crew-reduced vessels for shipowners and shipping companies*". The control of the unmanned barges, navigating wherever in the Flanders, is provided by licensed captains sitting in the Shore Control Centre in the company's office in Antwerp. The vessel is equipped with hardware and software: cameras, sensors and robotic components are integrated into the barge, and in the most advanced stage, the barge actually navigates autonomously with AI and machine learning and is supervised by the "*operators [who] monitor vessels where Seafar's server-based command & control software handles tasking, path tracking, and critical vehicle functions*". Moreover, they can provide data on the vessel performance to further optimise the operations.

Finally, opportunities to internalise and control the logistic chain open up for big shippers, which generally transport their supply of raw materials and the finished products from and to seaports. The same goes for ocean shipping carriers which already operate terminals in main ports and may consider autonomous barges to push the vertical integration of the transport sector for containers and offer a complete service, almost to the last mile.

PART III LEGAL CHALLENGES IN THE CONTRACT CHAIN

3.1 *Literature review*

Whilst the technology is promising and may also represent a business case for some actors, the introduction of autonomous barges requires changes in regulations which still provide for manning requirements. However, the European Committee for drawing up standards in the field of inland navigation (CESNI) is discussing whether linking the number of crew required not only to the size and the power of the vessel but also to the type of technology installed[108]. Safety regulations are, indeed, the main aspect that legal scholars have investigated regarding the introduction of autonomous inland navigation[109]. It is – in fact – completely absent an analysis of inland shipping contracts and risk distribution. Moreover, in the framework of the AUTOSHIP project, it has been tested whether current regulations may allow the use of an autonomous barge in the Flemish rivers and canals[110], while the authors

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[108] See Inland Waterway Transport's website.

[109] I. Bačkalov, *Safety of autonomous inland vessels: An analysis of regulatory barriers in the present technical standards in Europe*, in *Safety Science*, n. 128, 2020, pp. 104763.

[110] W. Nzengu - J. Faivre - A.S. Pauwelyn - V. Bolbot - L. A. Lien Wennersberg - G. Theo-

believe that existing rules allow the test of autonomous vessels, the full commercial implementation would require amendments as for now, the presence of an onboard operator is mandatory in several cases.

Dutch scholars[111] have compiled, on request of the Ministry of Infrastructure and Water Management of the Netherlands government, a research presenting the limits under the Dutch legislation. According to the authors, the definition of ship in dutch legislation is broad enough to contain unmanned vessels. Moreover, even though some of the provisions of the *Scheepvaartverkeerswet* require the presence of at least a boat master, they may be still applicable to a remote pilot, on the contrary, a fully autonomous vessel would not be able to accomplish the manning requirements. Interestingly the authors propose a "structural" solution, adding the phrase "or, failing that, the shipowner" as to clarify who is the party liable for the crew-related obligations in case of autonomous navigation.

It is also argued that the ministry should be granted the power to exempt autonomous vessels from crew requirements. The authors of the report advise, at least for the short-term and experimental use of autonomous vessels, the use of flexible tools like exemption (*ontheffingen*) which may be granted case by case by the ministry. In the perspective of a commercial implementation, individual exemptions may become a burden for the party; thus, the advice is for the minister to grant derogation to groups of defined categories of ships (*vrijstellingen*). In this context, the authors agree that the experimental parties will bear the liability for the risk that damage will be caused to third parties as a result of the experiment and to provide adequate financial security (mandatory insurance). The experiment is a hazard because it uses not fully developed technology and, in the meanwhile, asks for exemption from general safety rules, like crew onboard.

3.2 *Flemish Decree for innovation in shipping*

As already mentioned above, from 2019, thanks to a decree of the Flemish government[112], experiments about innovation in shipping are possible in the Belgian region waterways. The third chapter of the decree, titled "innovation in shipping" (*Innovatie in de scheepvaart*), contains two articles. The first, art. 50, presents the definitions. The second states, "*The waterway manager or the port authority can give permission for carrying out experiments or pilot projects within the area managed by the waterway manager or the port company, including the execution of test voyages, using innovative systems. Such systems include automated systems in vessels or ashore*".

The authorisations provide temporary exemptions (*afwijkingen*) from regulatory provisions on crew and vessel management, technical characteristics or equipment,

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TOKATOS, *Regulatory framework analysis for the unmanned inland waterway vessel*, in *WMU Journal of Maritime Affairs*, vol. 20, n. 3, 2021.

[111] F. SMEELE - F. STEVENS, *Juridisch Onderzoek Smart Shipping*, 2019.

[112] See footnote 15.

shipping traffic and operations on board and ashore. Nevertheless, rules on supervision and enforcement cannot be deviated, as much as the crime provisions. The exemption is granted for a maximum of one year and can be renewed for a total of five years. The experimenting party shall state the purpose of the experiments or pilot projects, the test area (waterways or parts of the port area), the rules they intend to be exempted from and the conditions under which those exemptions shall apply. Finally, they need to provide evidence of the safety measures taken.

3.3 *The legal definition of autonomous barges*

The first question about autonomous vessels is whether they can still be considered vessels. Many scholars[113] have tackled this in the maritime sectors, while in inland navigation, the research is still missing. To partially fill this gap, an examination of the main legislative instruments concerning inland navigation may help prove that autonomous barges fit into the definition of barges and that there is no ontological obstacle to the use of existing regulations and instruments insofar applicable. The results are presented in Table 1 below.

[113] G. Boi, *«Navi-drone»: primi interrogativi in tema di disciplina giuridica*, in *Rivista del diritto della navigazione*, n. 1, 2017, p. 177 ff.; V. Corona, *Le obbligazioni del vettore nel trasporto di cose con navi autonome o pilotate da remoto*, in *Diritto dei trasporti*, n. 2, 2019, p. 523 ff.; J.P. Rodriguez-Delgado, *The Legal Challenge of Unmanned Ships in the Private Maritime Law: What Laws would You Change?*, in *Il Diritto Marittimo – Quaderni*, vol. 5, 2018, pp. 498-505; E. Van Hooydonk, *The law of unmanned merchant shipping – an exploration*, in *The Journal of International Maritime Law*, n. 20, 2014, pp. 406-409; P. Zampella, *Navi autonome e navi pilotate da remoto: spunti per una riflessione*, in *Diritto dei trasporti*, n. 2, 2019, p. 597; A. Caligiuri, *A New International Legal Framework for Unmanned Maritime Vehicles?*, in A. Caligiuri (edited by), *Legal technology transformation. A practical assessment, Editoriale Scientifica*, Naples, 2020, p. 101 ff; Y. Van Logchem, *International Law of the Sea and Autonomous Cargo 'Vessels'*, in B. Soyer, A. Tettenborn (edited by), *Artificial intelligence and autonomous shipping: developing the international legal framework*, Hart Publishing, an imprint of Bloomsbury Publishing, Oxford, UK; New York, NY 2021.

8 mai 2019 - Loi introduisant le Code belge de la Navigation	Art. 1.1.1.3.9	«bateau de navigation intérieure» : un navire qui est exclusivement ou principalement destiné à la navigation sur les eaux intérieures, y compris un navire estuaire; l'enregistrement du navire dans un registre de bateaux de navigation intérieure est considérée comme étant une présomption que le navire est un bateau de navigation intérieure;
ADN	Art. 3	'vessel' shall mean any inland waterway or seagoing vessel.
CDNI 1996	Art. 1 (g)	"Vessel" means an inland waterway vessel, seagoing vessel, or floating equipment
CEVNI European Code for Inland Waterways	Art. 1.01, I, 1	1. The term "vessel" means any inland waterway craft, including small craft and ferry-boats, as well as floating equipment and seagoing vessels
CLNI 2012	Art. 1.2 (b)	"vessel" shall mean an inland navigation vessel used for commercial navigational purposes and shall also include hydrofoils, ferries and small craft used for commercial navigational purposes but not air-cushion vehicles. Dredgers, floating cranes, elevators and all other floating and mobile appliances or plant of a similar nature shall also be considered vessels;
Council Directive 2014/112/EU	Annex paragraph 2 (a)	(a) 'craft' means a vessel or item of floating equipment;
Directive (EU) 2016/1629	Art. 3 (a), (b), (c)	For the purposes of this Directive, the following definitions apply: (a) 'craft' means a vessel or item of floating equipment; (b) 'vessel' means an inland waterway vessel or seagoing ship; (c) 'inland waterway vessel' means a vessel intended solely or mainly for navigation on inland waterways;
Directive 2008/68/EC	Art. 2.6	'vessel' shall mean any inland waterway or seagoing vessel.
Dutch Civil code	Book 8. 3.	1. In the present Book (Book 8) an 'inland navigation vessel' shall mean: ships registered as 'inland navigation vessel' in the public registers referred to in Section 3.1.2, and ships not registered in those public registers that, according to their construction, are neither exclusively nor principally intended for floating on the sea.
International Convention for the Unification of Certain Rules of Law With Respect to Collision Between Vessels, 1910		No definition of vessel
CMNI		No definition of vessel
Loi du 5 mai 1936 sur l'affrètement fluvial (Belgium)		No definition of vessel
Geneva convention 1960		No definition of vessel

Table 1 *Definitions of barge in relevant legal instruments. Author's own composition*

In conclusion, the definition of the vessel also for inland navigation pertains to various aspects: the destination (inland waterways or also sea-going vessel), the purpose (commercial operations), the registration, or the qualities (floating). No definition requires a master, crew or other human factors to recognise a barge as such.

3.4 *The contract chain*

The commercial implementation of autonomous barges is not possible yet; in general, a master and crew are required onboard, and regulations need to be amended. Nevertheless, the only obstacle is not limited to the regulatory ambit; contractual and extracontractual liability provisions are also relevant. *De lege lata*, the introduction of autonomous barges may produce legal uncertainties and unbalances in risk distribution. This is undesirable as it may discourage barge owners and all the inland navigation stakeholders and play against the public acceptance of it. Many scholars have found liability to be one of the most urgent issues to solve[114]. The problem is not limited to the answer to the question of who is responsible in case of an accident. A persistent problem is whether, along the entire contract chain of barge construction and the carriage of goods, risks and advantages are equally distributed, or even better, shared by the stakeholders in a measure that they consider acceptable; only in this way all the relevant IN actors will invest in autonomous shipping.

In the following section, the CMNI and a charterparty form will be analysed to highlight whether the provisions are still applicable to autonomous barges or amendments may be necessary. Moreover, the shipowner's obligations (in its role of charting owner and/or carrier) derived from the charterparty or other contracts of carriage will be compared with the T&Cs of some companies providing semi-autonomous navigation software. If the software company is unwilling to assume some risks, those will be borne by the owner, who will be stuck 'between the devil and the deep blue sea'.

3.5 *CMNI*

The CMNI is a convention which regulates shipper and carrier liability when the transport is performed between two ports (or places of taking over and delivery) located in different countries, of which at least one is a party of the Convention. The Convention also applies for voyages performed in maritime waters as far as a maritime bill of lading has not been issued and the distance navigated in inland waterways is greater. To the scope of the Convention, the nationality of the vessel, its place of registration and homeport or whether it is a maritime or inland vessel is irrelevant. The same goes for the nationality or domicile of the shipper, consignee and carrier[115].

The main obligation of the carrier is to carry the goods and deliver them in the same condition as they received them and to do so on time[116]. Whereas artificial

[114] H. GHADERI, *Autonomous technologies in short sea shipping*, cit., p. 170; E. VERBERGHT, *Innovation in inland navigation failure and success the European case*, cit., p. 102; B. WIŚNICKI - N. WAGNER - P. WOŁEJSZA, *op. cit.*, p. 16; A. TSVETKOVA - M. HELLSTRÖM, *op. cit.*

[115] Article 2 CMNI.

[116] Article 3.1 CMNI.

intelligence may help provide better planning and in-time delivery, any delay caused by malfunctioning of the navigation software may determine a breach in the carrier's obligation towards the cargo interest parties. This may determine an economic burden for the carrier (the maximum amount for the delay is equivalent to the freight), and he/she should be able to recover it from the part which caused the stop. In this sense, the contract for the supply of the software must be drafted accordingly; however, the analysis of software licenses below suggests differently.

As many scholars[117] have pointed out for the maritime sector, seaworthiness is one of the most relevant aspects to assess. CMNI provides for an obligation of the carrier – before and at the beginning of the voyage – to exercise 'due diligence' to ensure that the vessel is cargoworthy, seaworthy, equipped and manned. While it is clear that an unmanned autonomous vessel cannot be considered seaworthy under this wording, there is still room to consider properly manned a remote-controlled unmanned barge, though, as the proper manning is a quantitative and qualitative indicator, a remote-controlled barge may be considered unmanned - for seaworthiness purposes - if the remote controller is supervising more vessels than allowed by regulations or he/she does not have special training.

Issues regarding seaworthiness do not stop at the manning requirements. In fact, insofar an AI software controls the barge and not only navigates the vessel, but it also operates the equipment and the safety systems (fire extinguishers, doors, etc.), its characteristics are relevant for the cargoworthiness. Establishing if a vessel is fit for the transport of determinate goods in foreseeable conditions when crew and master are not onboard anymore may be difficult even for an expert carrier. To assess the software, they may rely on third parties surveys, but this may be challenged

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[117] L. Carey, *All Hands Off Deck? The Legal Barriers to Autonomous Ships*, in *The Journal of International Maritime Law*, vol. 23, n. 3, 2017; F. Stevens, *Seaworthiness and good seamanship in the age of autonomous vessels*, in H. Ringbom - E. Røsæg - T. Solvang (edited by), *Autonomous ships and the law (IMLI studies in international maritime law)*, Routledge, Taylor & Francis Group, London New York, 2021; J.P. Rodriguez-Delgado, *The Legal Challenge of Unmanned Ships in the Private Maritime Law: What Laws would You Change?*, in *Il Diritto Marittimo - Quaderni*, vol. 5, 2018, p. 505 ff; J. Schelin, *Manning of unmanned ships*, in H. Ringbom - E. Røsæg - T. Solvang (edited by), *Autonomous ships and the law (IMLI studies in international maritime law)*, Routledge, Taylor & Francis Group, London New York, 2021, p. 272 ff; S. Baughen, *Unmanned Vessels and International Conventions for the Carriage of Goods by the Sea*, in B. Soyer - A. Tettenborn (edited by), *Artificial intelligence and autonomous shipping: developing the international legal framework*, Hart Publishing, an imprint of Bloomsbury Publishing, Oxford, UK; New York, NY, 2021, p. 83 ff; R. Williams, *Unmanned ships – a challenge to the current international regime regulating the carriage of goods?*, in B. Soyer - A. Tettenborn (edited by), *Ship operations: new risks, liabilities and technologies in the maritime sector (Maritime and transport law library)*, Informa Law from Routledge, Abingdon, Oxon New York, NY 2021; F. Stevens, *Carrier liability for unmanned ships*, in B. Soyer - A. Tettenborn (edited by), *Ship operations: new risks, liabilities and technologies in the maritime sector (Maritime and transport law library)*, Informa Law from Routledge, Abingdon, Oxon New York, NY, 2021. F. Siccardi, *Le navi autonome. Maritime autonomous surface ships (MAAS)*, in this *Journal*, 2019, pp. 848-862; V. Corona, *Le obbligazioni del vettore nel trasporto di cose con navi autonome o pilotate da remoto*, cit., p. 538; G. Boi, *«Navi-drone»: primi interrogativi in tema di disciplina giuridica*, cit., p. 196.

under the prohibition in the license to reverse engineering or anyway trace the source code of the software. It has been held that in the case of remote control, also the onshore 'wheelhouse' shall be considered when assessing the seaworthiness[118]. Moreover, the conditions in which the transport is to be performed will be more and more affected by cybersecurity. Scholars have argued in favour of considering cybersecurity as a component of seaworthiness, defining it as cyberworthiness[119].

Finally, two characteristics of the autonomous system, i.e. the connection (to the internet, to the provider cloud, to the SCC) and the interconnection between the systems onboard, may be argued to be relevant for the scope. Not only in their physical parts but in their intangible condition. It can be noted since now that the tech provider's T&Cs – which will be analysed below – exclude any liability concerning these aspects.

Under CMNI the shipper shall bear the liability of any damage and loss suffered by the carrier, in case, for example, the documents accompanying the cargo are missing, inaccurate or incomplete. However, if it is proved the fault of the carrier or his servants or agent, the first will be held liable. Thus a corrupted file containing the digital document stored in the servers of the tech provider may lead to liability for the carrier with little room for recourse against it, as it will be shown below. Moreover the possibility for the carrier to include reservation on the transport documents will require an agent of the carrier *in loco*.

The liability of the carrier is described in article 16. The carrier bears a presumed liability for any loss caused by delay, damage or loss of the cargo unless he/she can prove that the loss occurred in circumstances non-preventable by a diligent carrier leading to not avertable consequences. An error in the software controlling the entire navigation system cannot be considered unforeseeable by a carrier who decides to use an autonomous barge, as much as a cyberattack. However, the challenge is to set the extent to which diligence in preventing those errors and attacks must be used. The carrier is also liable for the action and the negligence (acts and omissions) of his servants and agents whose services he makes use of during the performance of the contract and when they are acting within the scope of their employment. Some considerations may be made on this point. In the case of an autonomous system, any actions or omissions determining issues resulting in a loss may have been (not) done before the actual performance of the contract (i.e. in coding), can this result in no liability for the carrier? In another

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[118] N. KAMPANTAIS, *Seaworthiness in autonomous unmanned cargo ships*, Thesis, Erasmus University, 2016.

[119] B. SŐZER, *Seaworthiness in the context of cyber-risks or "cyberworthiness"*, in B. Soyer - A. Tettenborn (edited by), *Ship operations: new risks, liabilities and technologies in the maritime sector (Maritime and transport law library)*, Informa Law from Routledge, Abingdon, Oxon New York, NY 2021; G. LELOUDAS, *Cyber Risks, Autonomous Operations and Risk Perceptions Is a New Liability Paradigm Required?*, in B. Soyer - A. Tettenborn (edited by), *Artificial intelligence and autonomous shipping: developing the international legal framework*, Hart Publishing, an imprint of Bloomsbury Publishing, Oxford, UK; New York, NY, 2021.

case, pointed out by a scholar[120], in which a former employee retains the password of the system and uses its access to disrupt the operations causing damages and loss, the carrier should not be held vicariously liable, at the same time not changing the passwords and deny access to former employees may be considered carrier's own negligence. More complex may be the case in which the person in consideration is a former employee of the tech provider. Another challenge to the vicarious liability of the carrier is exemplified by this job vacancy for a captain published on Seafar's website. Would a self-employed remote operator working with the tech provider be a sufficient link to ascertain the carrier liability?[121]

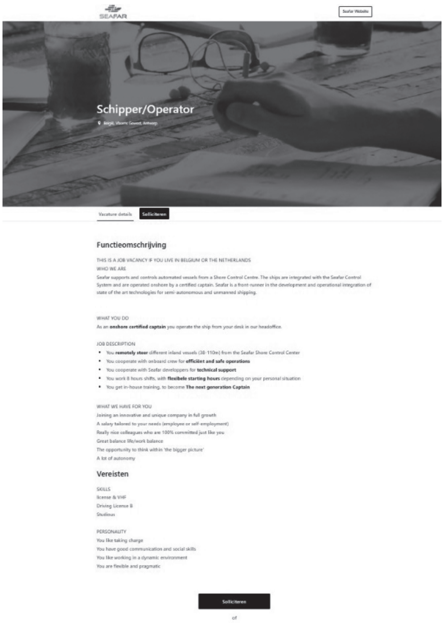

Figure 3 *Job offer for a remote operator on the Seafar's website. Screenshot taken the 26th of June 2022*

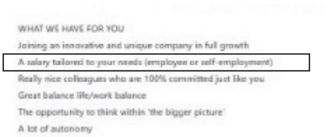

Figure 4 *Detail of Figure 3 showing the offer of self-employmentw*

[120] R. MACFARLANE, *Cyber-risk in shipping and its management*, in B. Soyer - A. Tettenborn (edited by), *Ship operations: new risks, liabilities and technologies in the maritime sector (Maritime and transport law library)*, Informa Law from Routledge, Abingdon, Oxon New York, NY 2021, p. 73.

[121] See M. MUSI, *La nozione di nave*, Bologna, 2020, pp. 127-128; M. MUSI, *The phenomenon of «MASS»: is it time to rethink the current maritime liability regime?*, in *Rivista del diritto della navigazione* n. 2, 2021, pp. 782-785, interestingly, in *Ibid.* p. 784, the author focuses on possible solutions for the Italian system.

The CMNI provides for a list of exemptions from carrier liability much shorter than the Hague-Visby Rules' one. None of them seems relevant in the case of an autonomous system as they refer to the role of the shipper, the nature of the goods, their packaging and marks, rescue or salvage operations and livestock transport. Other exemptions can be agreed upon contractually *ex*-art. 25, paragraph 2. Among these, the carrier, compliant with the seaworthiness obligation related to the crew, can be held free from liability for the loss caused by the act or omission of the master, the pilot or any other person in the service of the vessel. The contractual equivalent of the nautical fault in HVR is a non-viable option as an unmanned autonomous vessel will never be seaworthy under art. 3.3 CMNI. Another contractual exemption is the fire on board. In this case, the cargo interest party shall prove the fault of the carrier, their servants or agents or a defect of the vessel to see refund its damage, which may not be easy if the vessel is controlled by software. The latent defect is another contractual exemption authorised by the CMNI; the carrier shall prove that even with due diligence, the defect could not have been detected prior to the start. This clause may be outdated as a diligent carrier detecting an error during the voyage could remedy it, maintaining the software remotely.

Under CMNI, the carrier enjoys the possibility to limit its liability to 666,67 units of account per package or 2 units of account per kilo. If the carrier bears the compensation cost after the cargo interest action, it is important that he/she can recover the same amount from the tech provider if it caused the loss. However, this will be possible only if the liability in the contract with the latter is not capped to a much lower total.

Finally, the carrier may lose its liability exonerations and limitation rights if it is proved its intention or recklessness and the knowledge that the damage would probably result. Also, in this case, the burden of proof is on the cargo interest party, and it may be difficult evidence to find; however, with the advancing technology would not be surprising if operating an autonomous vessel and not updating an antivirus or not giving basic cybersecurity training to the employees would be considered recklessly.

3.6 *ESO terms & charterparty 2018*

The charterparty recalls the CMNI. Part 2, article 3, requires the owner to have all the documents and the certificates specified by AND "*completed, signed, valid and* onboard". In the same article, the master can issue a loading document "under protest" if, at the end of the tank loading, the cargo volume deviated from the one declared by the loading terminal. In article 3, paragraph 2, the master is required to keep a cargo journal, and bunker receipts for the last 3 months are kept "*on board*". The master signs the loading document and other cargo documents provided by the loading terminal and required by the charterer. Moreover, the acceptance of the data contained proved with the signature is binding "*in so far as he/she is capable of verifying the correctness*". It is foreseeable that with unmanned autonomous barges, those documents will not be kept on board in paper, but will be digitally stored on shore. As far as the control of the barge will be by AI software, the master will disappear or will be displaced on shore in an office. His/her presence at the terminal is unlikely. An agent of the owner may substitute him/her, but in this case, the wording needs to be modified anyway. It is possible, moreover, to imagine sensors on board being able to verify the cargo volume and issue automatic protest letters. In case the discharge is impeded by terminal restriction or deficiencies (art. 13.7), the master shall present a letter of protest to the terminal, which may still be possible automatically, as just said. However, the following obligation to "*use all the reasonable endeavours to have [it] signed by the Terminal representative*" may be beyond the possibilities of software.

In article 4, the obligation of the owner to advise the charterer in case of delay on arrival could be simplified by technology which will allow the charterer to know exactly where the barge is without relying on what "the owner or the master have reason *to believe*". The same goes for the duty of the owner to send messages about the current position and update on the estimated time of barge arrival. This could be easily done by the system itself.

The owner has the right to nominate a barge in due time. The charterer can reject the barge based on the EBIS programme inspection and standard of acceptance developed by themselves, art. 10.3 states that a barge should not be unreasonably rejected, but it is doubtful if it can be rejected on the basis of being autonomous.

According to article 10.9, the owner is obliged to use the utmost care in loading, stowage, custody and delivery of the cargo. The duty does not stop at the beginning of the voyage. Although it is imaginable that the loading and the stowage may happen autonomously (i.e. automatic pumps), even in autonomous vessels, it can be performed in a traditional way. However, when the barge is sailing autonomously, the custody of the cargo, for which the owner shall use the utmost care, will be performed by the autonomous system, which software to use needs to be a thoughtful choice for the owner. Is the owner entrusting the custody to an automated system fulfilling its duty of care? Will the owners, who are supposed to be experts of inland navigation and not of AI systems, fulfill their obligation with software widely used in the market, or will they be bound to the best technology available? It is likely that the transport of dangerous goods such as oil with autonomous vessels will be regulated more strictly, but the same considerations may apply to any kind of cargo when it comes to test the cargoworthiness of the barge.

Article 10.10 contains a hold harmless clause in case the operations of loading and discharging are blocked by the shore installation because of leakage or contamination, which decreases the quality of the product. In this case, the owner shall defend the charterer against any and all claims. If the barge is controlled by an autonomous system is likely that an error in the software provoked the damage, for example, the segregation between different cargos was not complete. Depending on the contract clauses between the owner and the software provider, the owner may not be able to recover from the latter the expenses, and he/she will bear all the risks.

Art. 11 of the charterparty deals with the inspection of the tank, and art. 19 with the inspections of the barge or the cargo. The charterer may require an inspection at their expense. The inspection considers the state of the tank or the barge itself and, at first sight, it may not cause any problem whether the barge is autonomous or not. The inspection is done for safety reason because any accident in oil transport leading to leakage and pollution bring with it a reputational risk for the oil company itself. In the case of autonomous navigation, the safety requirements may lead to a request by the charterer (which may be demanded by the shippers themselves) to inspect the software with another AI software. Software inspection performed by another company designated by the charterer may raise multiple challenges and concerns related to intellectual property, trade secrets, and reverse engineering. Moreover, as the developer retains the property of the software, this possibility shall be provided for also in the license or any other software contract between the service provider and the owner.

The barge owner also bears the risk (and the expense) for the discharging of the cargo. Once again, if the process is automatised and controlled by the AI system, in case of an error in this phase and without an adequate contractual balance along the chain, the owner may be the only actor assuming the risk.

The confidentiality clause, stated in art. 25, bounds the owner to secure that the data related to (or arising from) the charterparty are not divulgated or published by him/herself or their employees, servants or agents. It is likely that the data considered at the time did not take into account the amount of data which will be produced, used and collected with the implementation of autonomous navigation. However, the service providers will keep the data and use it to improve their service. A clear agreement with the latter for the use and exploitation of these data is thus crucial.

3.7 *Software contracts*

The analysis of the charterparty has highlighted how relevant it is for the ecosystem actors to look not only at the single contracts but to zoom out and consider the entire chain to avoid unbalances in the risk distribution. It is worth considering then some Terms and Conditions applied by companies located in Europe that provide solutions for automation in shipping. Four T&Cs are analysed. Wärtsilä Marine (2022), Wärtsilä Digital Solutions (2022), Tresco Engineering bv and Periskal cvba. They are all freely available on the companies' websites. The results of the analysis are organised in table 2, which gives an overview of which clauses are included in the documents and which are absent.

	License of the software	Limit to use	Maintenance, upgrade, updates included	Supplier's liability	Liability limitation	Liability exemption	Costumer's liability for the user	Cybersecurity exemption + data exploitation	Third party claim indemnity	Third party's use	Back to back clause	Warranty + warranty exclusion	Claims for defects time limit	Hardship	Suspention	Force Majeure
Wärtsilä Digital Solutions 2022	y	y	n	y	y	y	y	y	y	y - T&C apply	y - T&C of Third party software inc.	y	/	/	y	y
Wärtsilä Marine 2022	y	y	n	y	y	y	/	y	y	y - T&C apply	y - T&C of Third party software inc.	y	y	y	/	y
Tresco Engineering bv	y	/	/	n	/	y	/	y	/	/	/	/	y	/	/	y
Periskal Group	y	/	n	n	/	y	/	/	/	y - with consent	y - manufacturer warranty	/	y	/	/	y

NOTES: y = yes; n = no; / = not available

Table 2 *Contractual clauses in T&Cs of companies providing for semi-autonomous navigation software. Author's own composition*

In general, Wärtsilä's T&Cs (which contain a cross-reference to each other's) may be considered more complete and complex, while Periskal and Tresco's T&C are silent on some aspects[122].

In the four analysed cases, all the T&Cs provide for a non-exclusive license ("right to use", in the case of Periskal), and the companies (or third parties) retain the intellectual property and the ownership of the software. In some cases (Wärtsilä), the copy is allowed only when essential or for backup purposes. Otherwise, it is forbidden to "*copy, adapt, modify, create derivative works from, reverse-engineer, disassemble, decompile or otherwise attempt to derive the source code*". Whether any of these operations may be necessary for inspections of the software (even in case of class inspection), issues may arise.

Congruent with the tendency to servitisation which has been shown above, the companies do provide not only the software and the parts, but also maintenance, optimisation and analytics. However, three out of four T&Cs stated that maintenance, update, upgrades and other services are not included and are subject to separate agreements and further costs. This is important, considered that in one case, the warranty is excluded if the customer fails to implement the provider's updates.

The barge owner shall well ponder contractual clauses on indemnity and liability exemptions because he/she may find himself bearing responsibilities outside its control without the possibility to pass the risk or recover the expenses. The obligations that he/she assumes with the charterparty may be onerous, and in case of damage caused by the software, he/she may not have a counterclaim against the provider. All the T&Cs provide liability exemption clauses. Wärtsilä DGexcludes all the liabilities (including for negligence) "*to the fullest extent permitted by law*". The barge owner bears the sole liability for the use of the software. Liability for

[122] It can be observed that some companies, such as Seafar, do not have public available T&Cs on their website, while others, i.e. Argonics, have a webshop where software and upgrades are available for sale, but no T&Cs are traceable. Two software (collision alert and AIS tracking) are offered on a one-time purchase basis, and a package for support and tracking is available for a yearly contract, in this case the updates and maintenance seem included, while the upgrade is available as well with a yearly subscription.

loss of profits, use, business opportunities, revenue, and reputation are explicitly excluded, among others. Moreover, the supplier excludes any liability for any technical advice and technical recommendation to the customer. The T&Cs are explicit in exempting the company from liability "*for any accident, damage or delay caused by or to any vessel or other premises owned or operated by the Customer or any other person whether or not the accident or damage is related to the use, reliance upon, operation or failure of the Solutions*". In Wärtsilä Marine T&Cs the liability for the failure of the software because of the incompatibility with other parts or equipment not provided by the company is excluded. In the case of Tresco and Periskal the liability is excluded completely in case of fault or negligence by both the company or any of its employees. Periskal seeks to avoid liability "*for any damage caused by the functioning or non-functioning of the software and hardware.*" The Wärtsilä T&Cs present also a limitation to the liability exposure of the company towards the client that accounts for the entire amount of the price paid by the customer in the precedent twelve months in one case, and in the other to 1/3 of the price paid for the services related to the vessel at issue. Wärtsilä in DG T&Cs assumes responsibility without limitation for fraud or fraudulent misrepresentation and for negligence (also vicarious liability) only in case of death or personal injuries, while in Marine T&Cs, the unlawful intent, wilful misconduct or gross negligence by one of its statutory representatives or directors has as a consequence the loose of the right to limit its liability.

Clauses related to cybersecurity are becoming more and more common, however, a barge owner may want to consider thoughtfully the prevision excluding liability for any damage connected to cybersecurity even in the case this affects its systems[123]. In the same context of interdependency and multiple software and equipment necessary to make the autonomous system able to navigate, also the exemption of liability for the consequences of the integration of the tech provider's software with other systems may become a burden that the shipowner alone must carry.

Two T&Cs contain provisions granting the tech provider the right to collect and use the data, to maintain such data after termination or expiration of the contract and to own any enrichment which may derive from them. From data, multiple issues may arise, from their use as evidence to the privacy rights of third parties (i.e. the navigation along narrow channels permits the camera used to navigate to detect people, cars, and everything is present in the surroundings), etc. Moreover, some of the T&Cs contain provisions to exempt the tech provider from liability linked with data storage.

Especially in the case of transport of dangerous goods, an error in the software that controls the vessel may end up in an extreme polluting event, which in inland

[123] See the air conditioning case in R. MACFARLANE, *Cyber-risk in shipping and its management*, cit.

navigation may easily damage the water and the surrounding. In this case, however, two clauses in Wartsila Marine exclude any liability on the tech provider for cleaning up, removing, and disposing of those materials, also "*the customer shall indemnify the Supplier in respect of and against any claims, fines, penalties and all related expenses arising in connection with such waste material or Hazardous Materials escaping to or from the vessel, the Equipment or Spare Parts*". Such indemnity is also valid for any claim from third parties relating to the contract.

Particularly relevant in the contract chain are also the clauses dealing with the use of the software by third parties, which may correspond to the owner of the vessel in the case the contract with the provider is between the latter and the shipyard or between the registered owner and the bareboat charterer. Wärtsilä T&C warns the costumers to inform of and make third parties and/or users accept the T&Cs[124], and that they shall be liable for any acts and omission by third parties; moreover, it is stated that "*supplier will have no obligation to provide support or other services or remedies to Customer's customers or other end users*". Such clauses are not present in Periskal and Tresco T&Cs with the only explicit exclusion of any right to sell, rent or secure the software to third parties; the use free of charge shall be approved by Periskal, whether the use free of charge is difficult to establish when a barge equipped with the software is hired by the (bareboat) charterer.

Only Wärtsilä T&Cs present a warranty period in which the company assure that the software does not contain any "*material non-conformance with Supplier's technical specification for such software*", while the warranty for the cloud is that it will perform *substantially* accordingly to the specifications, in fact, "*Supplier does not guarantee that the Solutions will be performed error-free, virus-free, free from vulnerabilities or uninterrupted, or that Supplier will correct all service errors*". Moreover, the customer shall behave appropriately to mitigate losses or damages, which may mean interrupting the operations; otherwise, the warranty right will be deemed waived. Relevant – if considered that one of the most important factors for autonomous shipping is the possibility of seamless navigation also during the night – is the clause for which services under warranty are performed only during working hours. Warranty does not apply to products and services which have been agreed to be used for trial purposes.

Additionally, the supplier's right (Wärtsilä) to suspend the service for maintenance, modification or improvement may have a substantial impact on the barge operation without this possibly being considered a breach of contract.

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[124] From their side the tech providers – in case their supply relies on a third party software or product – recall in the contract with the costumers the relevant T&Cs or pass the responsibility for the maintenance to the manufacturer. Moreover, a back-to-back clause is drafted in Wärtsilä T&Cs. "*if Supplier's suppliers of products and services used in the Solutions increase their prices or change the terms relating thereto, [it shall] pass such increases or changes on to Customer*". Such a clause shall not be underestimated by the barge owner, especially whether he/she hires the barge to a charterer for a long period of time. Periskal, for its part, passes the liability for the accuracy and the data used in the maps to the national body which provide the information.

Finally, only one T&Cs presents a hardship clause, while all four contain a force majeure clause; quite interestingly, Wärtsilä explicitly nominated "cyber incident" among the force majeure events.

3.8 *A problem of qualification?*

Tech companies providing software for certain degrees of automatisation in navigation seek to be untouched by whatsoever liability. However, in inland shipping, as in other sectors, some of the companies offering the SCC service also provide the software and the equipment to make the barge semi-autonomous - as said above - define themselves as ship-manager. Hunter explores the possibility of applying the BIMCO SHIPMAN to those companies. "*Ship managers using SHIPMAN have very limited exposure to liability. The managers are liable only for loss, damage, delay, or expense resulting 'solely from' their 'negligence, gross negligence, or wilful default'. Even if the managers are proved to have acted intentionally or recklessly, their liability is capped at ten times the annual management fee for each incident or series of incidents. [..] Similarly, the managers are not liable for "crew" negligence unless they have been negligent in managing the crew and this would most likely still apply in the context of shore-based controllers.*"[125] This applies to remote-controlled operations. When the ship management company still provides for the remote captains. Whether this will be still the case in fully autonomous shipping is impossible to tell. The company providing self-learning artificial intelligence software that fully controls a barge, which performs the navigation, transports the cargo, controls the systems on board to protect the cargo and the vessel, issues digital documents, etc., may still be considered only as a ship manager? Shall it better be recognised as a carrier or actual carrier?[126] Qualifying the tech provider as a carrier would change fully its rights and obligations, and subject its contract freedom on liability to mandatory provisions in international conventions and national laws.

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[125] G. HUNTER, *Standard contracts for the MASS(es) – charter parties and other agreements for autonomous ships, in* B. Soyer - A. Tettenborn (edited by), *Ship operations: new risks, liabilities and technologies in the maritime sector (Maritime and transport law library)*, Informa Law from Routledge, Abingdon, Oxon New York, NY, 2021, pp. 214-219.

[126] This seems excluded by some scholars, see V. CORONA, *Le obbligazioni del vettore nel trasporto di cose con navi autonome o pilotate da remoto*, cit., p. 547.

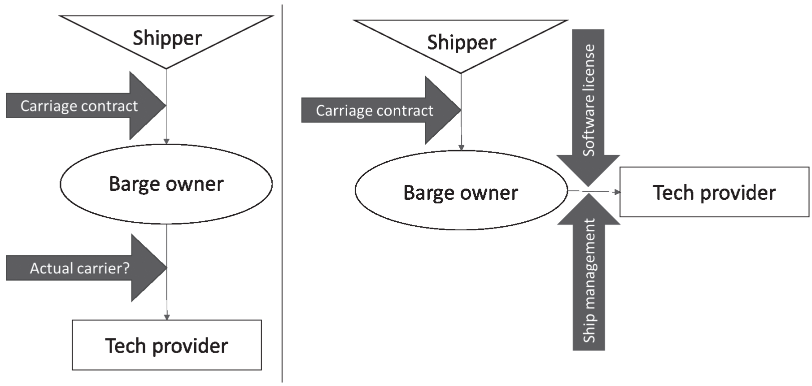

Figure 5 *Possible contractual arrangements for autonomous inland shipping. Author's own composition.*

Conclusion

Implementing autonomous technologies would help make the inland navigation sector safer, greener, and more reliable and push the modal shift from road transport to inland shipping. As much as in other transport modes, the introduction of autonomous navigation systems may have a profound impact on the sector's market structure, challenging the opportunity of ownership, shifting toward digital servitisation and squeezing the market shares in the hand of bigger companies. Tech providers, ranging from software providers to system integrators and shore control centres, will gain a prominent role among the ecosystem actors. From a legal perspective, autonomous barges may still be considered barges, and a new system *ad hoc* is unnecessary. However, regulations need to be amended to assure the commercial implementation of autonomous unmanned vessels, *in primis,* the safety manning requirements. The presence of a master and crew onboard is still relevant to assess the seaworthiness of the barge; however, scholars have already defined cyberworthiness as part of the seaworthiness assessment. The widespread use of autonomous barges can also be hindered by unbalances in risk distribution. If only one actor (the shipowner) assumes the entire responsibility because of bottlenecks along the contractual chain, it may discourage the investment. The analysis of the CMNI obligations for the carrier and the ones arising from a charterparty compared with the T&Cs of companies providing software for semi-autonomous navigation proves that the carrier/shipowner risks getting trapped with liabilities arising from cargo interest party claims without a counterclaim against the software provider. Moreover, the obligation to cover the latter's cost and hold them harmless in case of claims against them, thanks to the indemnity clauses inserted in the T&Cs, will be an additional burden. For some of the traditional actors, mandatory rules on liability and limitation apply; as introduced in this paper, it may be the case to qualify some new actors differently. Finally, current laws and international conventions may need to be amended or exempted to clear the way from any uncertainties; however, any intervention on these instruments is longer and more complex than balancing the parties' interests contractually. A fair contractual risk distribution allows all the actors to acknowledge their risks and interests and insure them, paving the way toward the implementation of autonomous barges.

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